US009082336B2

(12) **United States Patent**　　　(10) **Patent No.:**　　**US 9,082,336 B2**
Pantfoerder　　　　　　　　　　　　　(45) **Date of Patent:**　　***Jul. 14, 2015**

(54) **LUMINESCENCE SHOCK AVOIDANCE IN DISPLAY DEVICES**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventor: **Kai Achim Pantfoerder**, Cupertino, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/279,746**

(22) Filed: **May 16, 2014**

(65) **Prior Publication Data**

US 2014/0247234 A1　　Sep. 4, 2014

Related U.S. Application Data

(63) Continuation of application No. 13/777,072, filed on Feb. 26, 2013, now Pat. No. 8,743,161, which is a continuation of application No. 13/304,176, filed on Nov. 23, 2011, now Pat. No. 8,405,688, which is a

(Continued)

(51) **Int. Cl.**
　　G09G 5/10　　　　(2006.01)
　　G09G 3/20　　　　(2006.01)
　　G06F 3/041　　　(2006.01)

(52) **U.S. Cl.**
　　CPC *G09G 5/10* (2013.01); *G06F 3/0416* (2013.01); *G09G 3/20* (2013.01); *G09G 2320/0606* (2013.01); *G09G 2320/0626* (2013.01); *G09G 2320/0633* (2013.01); *G09G 2360/144* (2013.01)

(58) **Field of Classification Search**
　　CPC G09G 5/02; G09G 2320/0666; G09G 2320/0626; G09G 2320/0233; G09G 2360/144; H04N 1/60
　　See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,516,055	A	5/1985	Nelson
5,483,261	A	1/1996	Yasutake
5,488,204	A	1/1996	Mead et al.
5,825,352	A	10/1998	Bisset et al.
5,835,079	A	11/1998	Shieh

(Continued)

FOREIGN PATENT DOCUMENTS

| JP | 2000-163031 A | 6/2000 |
| JP | 2002-342033 A | 11/2002 |

OTHER PUBLICATIONS

Final Office Action mailed Aug. 2, 2010, for U.S. Appl. No. 11/800,293, filed May 4, 2007, 17 pages.

(Continued)

Primary Examiner — Antonio A Caschera
(74) *Attorney, Agent, or Firm* — Kendall P. Woodruff

(57)　　　　**ABSTRACT**

A luminescence shock avoidance algorithm selectively limits the brightness level of a display device when the display device is activated in a dark environment to prevent the temporary vision impairment that can occur when a display device is activated in a dark environment. The algorithm receives the state of the display (e.g. on or in standby mode), and can optionally receive an ambient lighting value from an ambient light sensor and a user-selectable manual brightness adjustment setting to determine whether luminescence shock avoidance should even be triggered, and if it is triggered, how much should the brightness level of the display be limited.

11 Claims, 7 Drawing Sheets
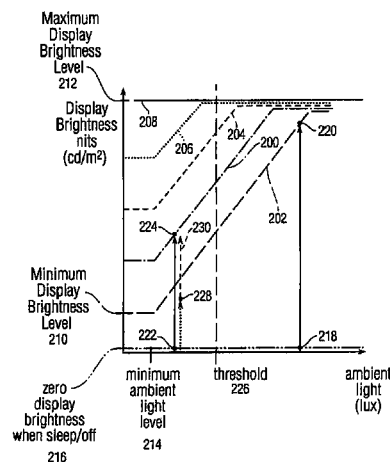
Related U.S. Application Data

continuation of application No. 11/800,293, filed on May 4, 2007, now Pat. No. 8,068,125.

(60) Provisional application No. 60/878,755, filed on Jan. 5, 2007.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,880,411	A	3/1999	Gillespie et al.
6,094,185	A	7/2000	Shirriff
6,188,391	B1	2/2001	Seely et al.
6,310,610	B1	10/2001	Beaton et al.
6,323,846	B1	11/2001	Westerman et al.
6,529,212	B2	3/2003	Miller et al.
6,690,387	B2	2/2004	Zimmerman et al.
6,713,745	B2	3/2004	Lin et al.
6,762,741	B2	7/2004	Weindorf
6,865,405	B2	3/2005	Lin
7,015,894	B2	3/2006	Morohoshi
7,095,392	B2	8/2006	Lin
7,184,064	B2	2/2007	Zimmerman et al.
7,221,374	B2 *	5/2007	Dixon 345/591
7,605,829	B2	10/2009	Oh
7,663,607	B2	2/2010	Hotelling et al.
7,701,434	B2	4/2010	Kreek et al.
8,068,125	B2	11/2011	Pantfoerder
8,405,688	B2	3/2013	Pantfoerder
2005/0117062	A1	6/2005	Chien et al.
2006/0026521	A1	2/2006	Hotelling et al.
2006/0197753	A1	9/2006	Hotelling
2007/0040774	A1	2/2007	Lee et al.
2007/0222730	A1	9/2007	Kao et al.
2008/0158172	A1	7/2008	Hotelling et al.
2008/0165203	A1	7/2008	Pantfoerder

OTHER PUBLICATIONS

Final Office Action mailed Apr. 6, 2011, for U.S. Appl. No. 11/800,293, filed May 4, 2007, 17 pages.
Lee, S.K. et al. (Apr. 1985). "A Multi-Touch Three Dimensional Touch-Sensitive Tablet," Proceedings of CHI: ACM Conference on Human Factors in Computing Systems, pp. 21-25.
Non-Final Office Action mailed Feb. 16, 2010, for U.S. Appl. No. 11/800, 293, filed May 4, 2007, 14 pages.
Non-Final Office Action mailed Dec. 3, 2010, for U.S. Appl. No. 11/800, 293, filed May 4, 2007, 15 pages.
Notice of Allowance mailed Aug. 10, 2011, for U.S. Appl. No. 11/800, 293, filed May 4, 2007, 9 pages.
Rubine, D.H. (Dec. 1991). "The Automatic Recognition of Gestures," CMU-CS-91-202, Submitted in Partial Fulfillment of the Requirements of the Degree of Doctor of Philosophy in Computer Science at Carnegie Mellon University, 285 pages.
Rubine, D.H. (May 1992). "Combining Gestures and Direct Manipulation," CHI '92, pp. 659-660.
Westerman, W. (Spring 1999). "Hand Tracking, Finger Identification, and Chordic Manipulation on a Multi-Touch Surface," A Dissertation Submitted to the Faculty of the University of Delaware in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Electrical Engineering, 364 pages.
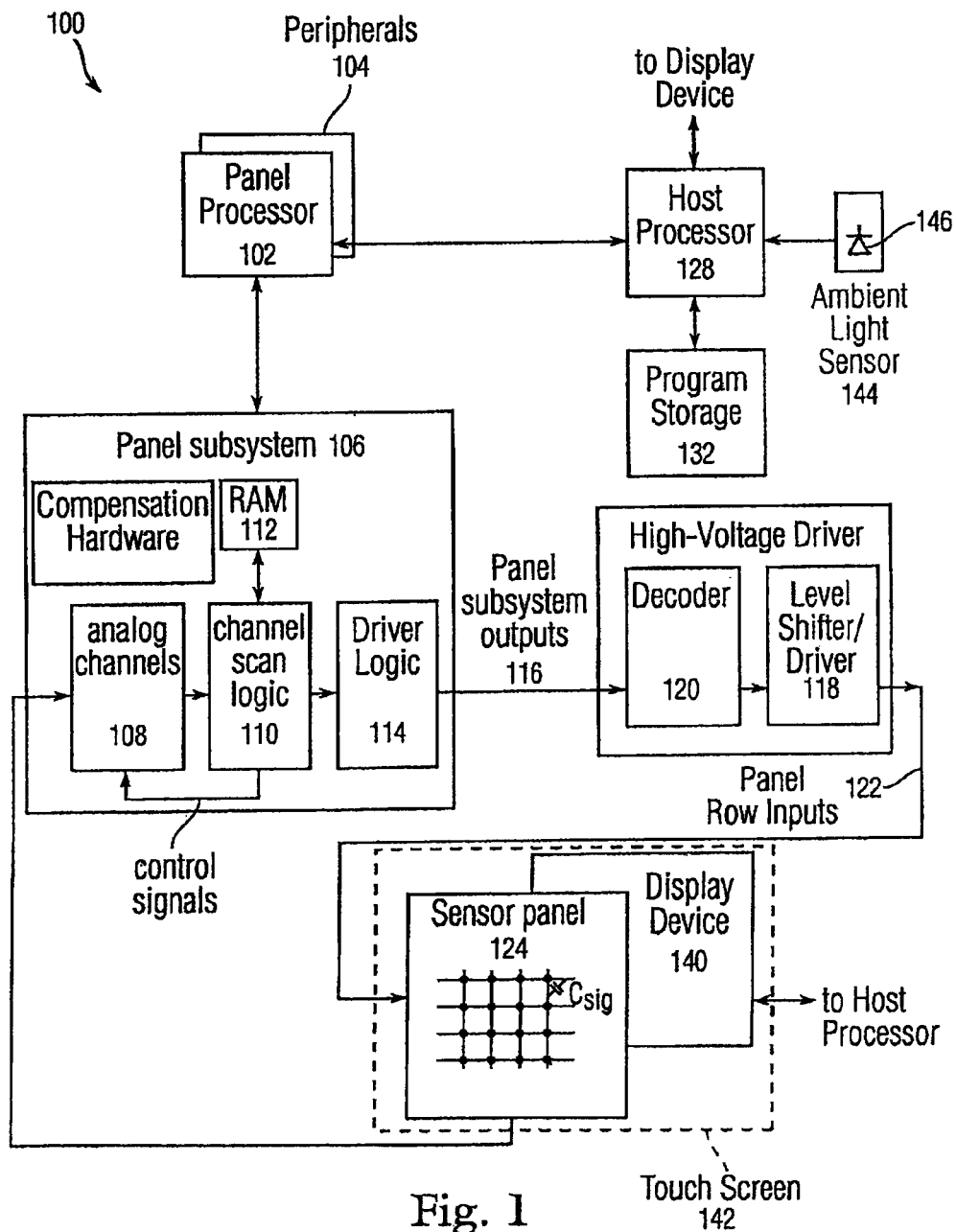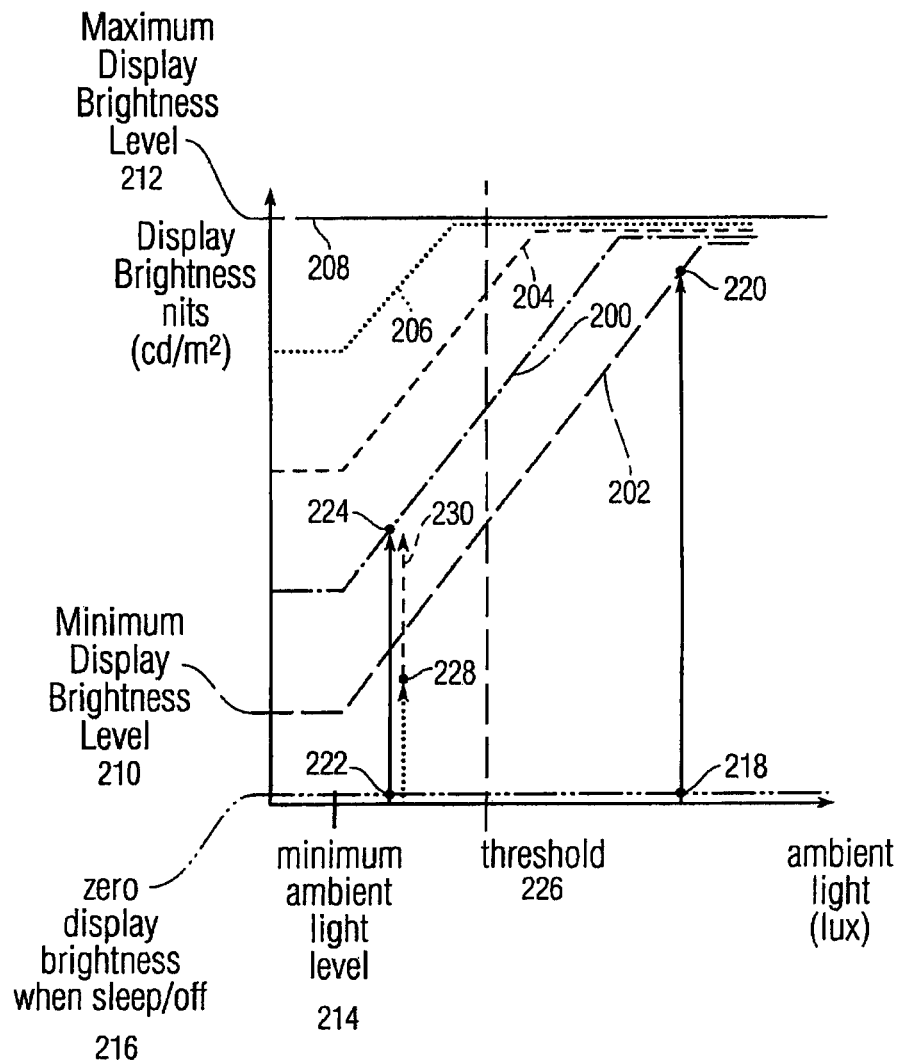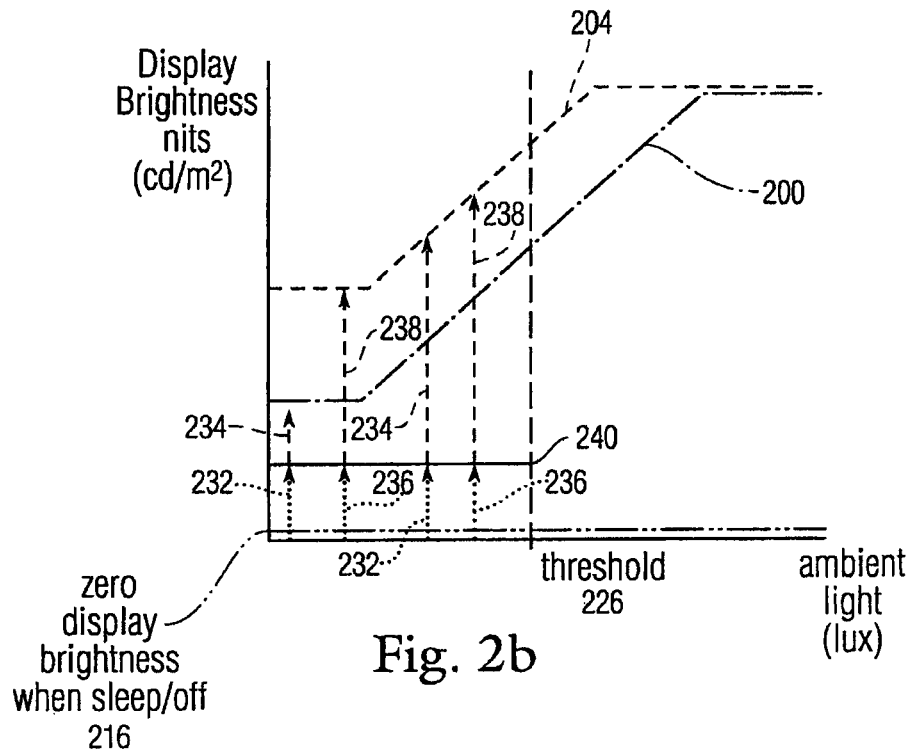
* cited by examiner

100

Peripherals
104

Panel
Processor
102

to Display
Device

Host
Processor
128

146

Ambient
Light
Sensor
144

Program
Storage
132

Panel subsystem 106

Compensation
Hardware

RAM
112

analog
channels
108

channel
scan
logic
110

Driver
Logic
114

Panel
subsystem
outputs
116

High-Voltage Driver

Decoder
120

Level
Shifter/
Driver
118

Panel
Row Inputs
122

control
signals

Sensor panel
124

Display
Device
140

C_{sig}

to Host
Processor

Touch Screen
142

Fig. 1

Fig. 2a

Display
Brightness
nits
(cd/m²)

204

238

200

234

234

240

232

236

236

232

zero
display
brightness
when sleep/off
216

threshold
226

ambient
light
(lux)

Fig. 2b

Display
Brightness
nits
(cd/m²)

204

244
244

242

200

234

246

234

240

232

242

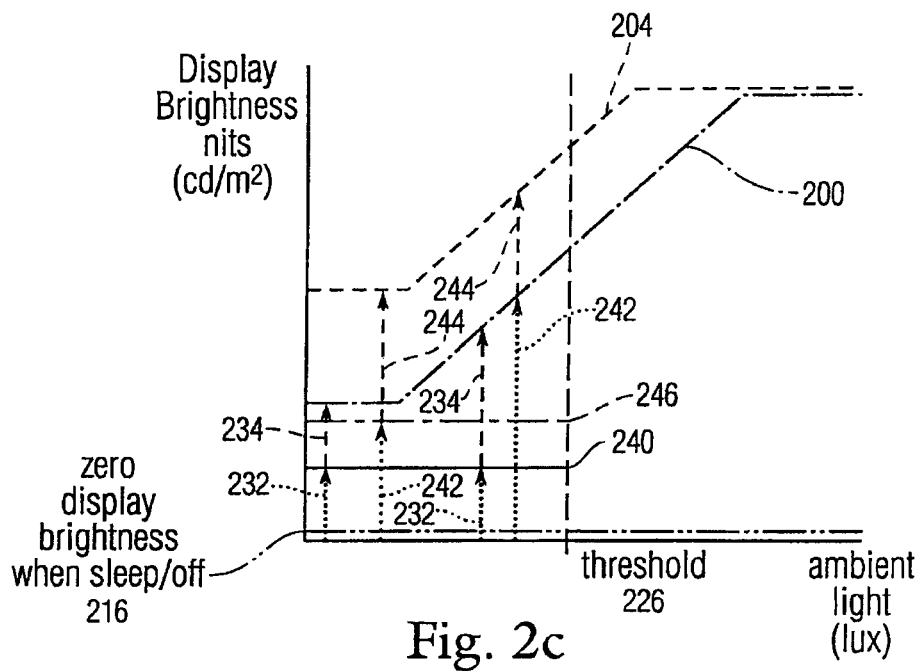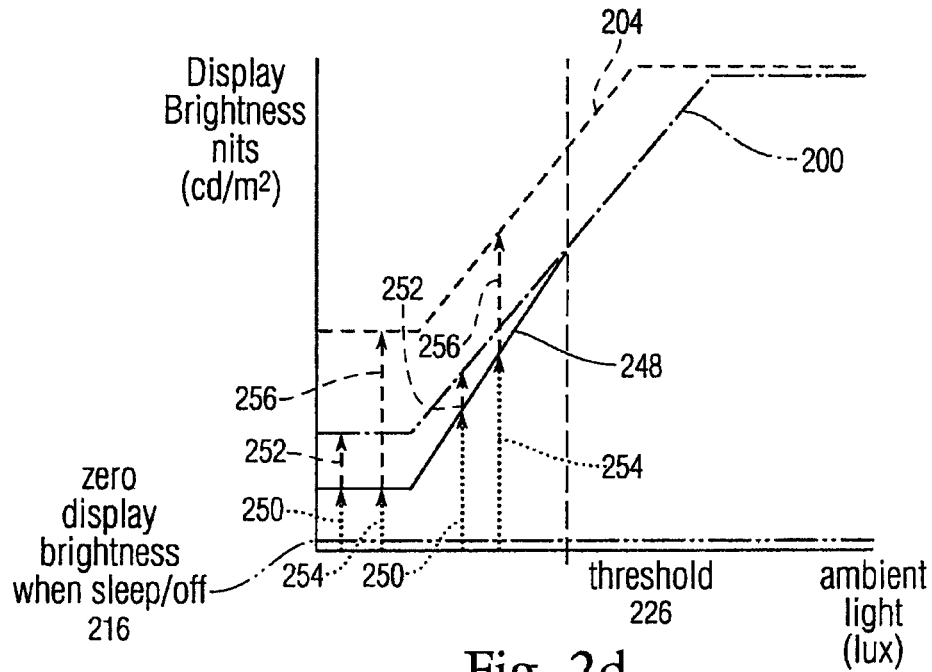232
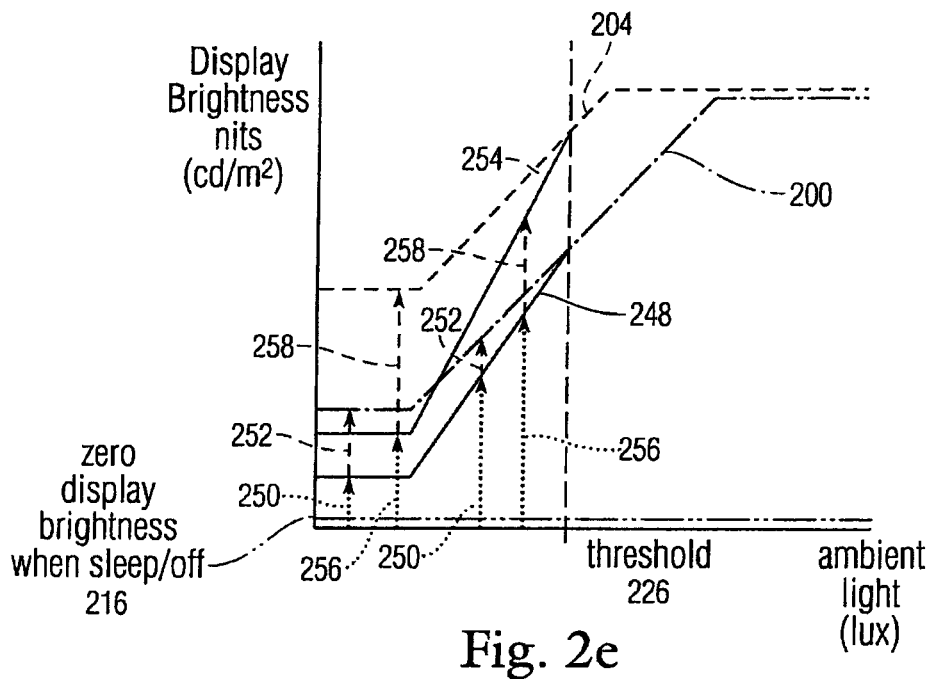
zero
display
brightness
when sleep/off
216

threshold
226

ambient
light
(lux)

Fig. 2c

Fig. 2d

Fig. 2e

Fig. 2f

Fig. 3

Fig. 4

Sensor
Panel

524

Display
Device
530

Mobile
telephone
536

Fig. 5a

Sensor
Panel
524

Display
Device
530

Digital
Audio / Video
Player
538
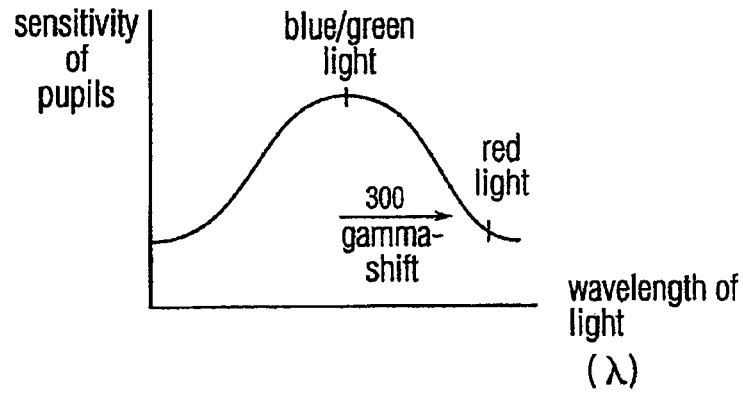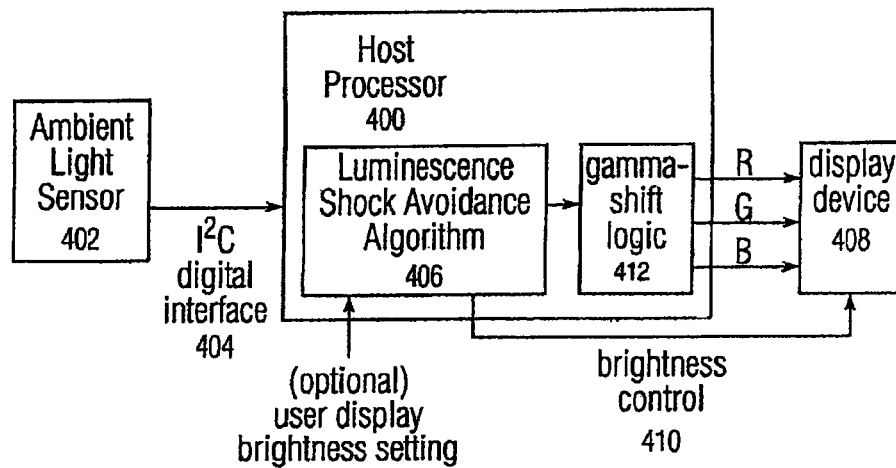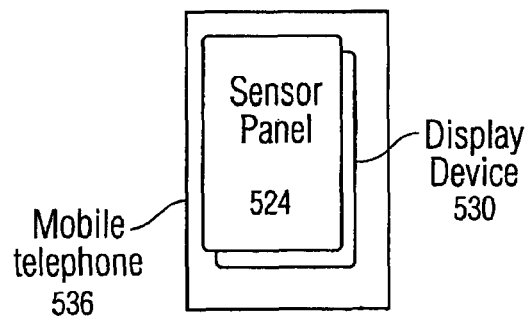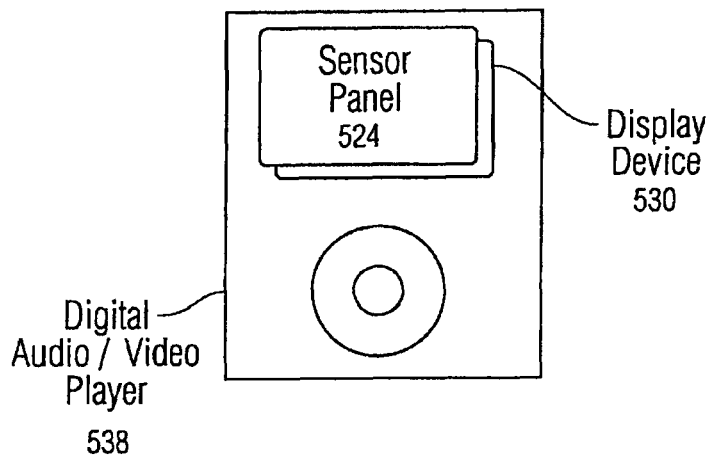
Fig. 5b

LUMINESCENCE SHOCK AVOIDANCE IN DISPLAY DEVICES

This application is a continuation of U.S. patent application Ser. No. 13/777,072, filed Feb. 26, 2013, which is a continuation of U.S. patent application Ser. No. 13/304,176, filed Nov. 23, 2011, now U.S. Pat. No. 8,405,688, issued Mar. 26, 2013, which is a continuation of U.S. patent application Ser. No. 11/800,293, filed May 4, 2007, now U.S. Pat. No. 8,068,125, issued Nov. 29, 2011, which claims priority to U.S. Provisional Patent Application 60/878,755, filed on Jan. 5, 2007, each of which is hereby incorporated by reference herein in its entirety. This application claims the benefit of and claims priority to U.S. patent application Ser. No. 13/777, 072, filed Feb. 26, 2013, U.S. patent application Ser. No. 13/304,176, filed Nov. 23, 2011, now U.S. Pat. No. 8,405, 688, issued Mar. 26, 2013, U.S. patent application Ser. No. 11/800,293, filed May 4, 2007, now U.S. Pat. No. 8,068,125, issued Nov. 29, 2011, and U.S. Provisional Patent Application 60/878,755, filed on Jan. 5, 2007.

FIELD OF THE INVENTION

This invention relates to display devices, and more particularly, to avoiding luminescence shock (temporary vision impairment) when a display device is activated in a dark environment.

BACKGROUND

Many types of input devices are presently available for performing operations in a computing system, such as buttons or keys, mice, trackballs, touch panels, joysticks, touch screens and the like. Touch screens, in particular, are becoming increasingly popular because of their ease and versatility of operation as well as their declining price. Touch screens can include a touch sensor panel, which can be a clear panel with a touch-sensitive surface. The touch sensor panel can be positioned in front of a display screen so that the touch-sensitive surface covers the viewable area of the display screen. Touch screens can allow a user to make selections and move a cursor by simply touching the display screen via a finger or stylus. In general, the touch screen can recognize the touch and position of the touch on the display screen, and the computing system can interpret the touch and thereafter perform an action based on the touch event.

Because touch screens can reduce or eliminate the need for physical keypads or buttons, the touch screens themselves can often be made larger in comparison to the overall size of the device. These larger touch screens have enabled even small devices such as personal digital assistants (PDAs), mobile telephones, digital audio/video players, and the like to provide a wider variety of content than previously possible, including video, graphics, Internet access, photos, and the like. The convenience of today's handheld portable devices combined with their ever-increasing multi-media functionality has made such devices seemingly ubiquitous, with users carrying them everywhere, in purses or clipped to belts. To a dedicated user, these personal devices can be as indispensable as a wallet. To that end, users may place these personal devices within arms reach wherever they go, including vehicles, movie theaters, and the like.

Because personal devices tend to have small batteries, power savings is critical. A large display illuminated to full brightness will exhaust a battery in no time, and thus power saving functions such as sleep modes are common in personal devices. For example, the display of a mobile telephone may

be dimmed or go dark altogether until a call is received, or the screen of a PDA may go blank until the user activates a function or a communication such as an e-mail or text message is received. However, if one of these personal devices is in a sleep mode in a dark environment and the display is suddenly illuminated due to a received call or other communication, a nearby user who happens to be looking at the device or is instinctively drawn to looking at the display when it illuminates can suffer temporary vision impairment. Because the user's pupils have opened up in the dark environment, the sudden flash of light can cause short-term blindness or at least impaired vision. This temporary impaired vision can range from a mere annoyance to a life-threatening situation if the user is driving a motor vehicle.

SUMMARY

A luminescence shock avoidance algorithm can be employed to selectively limit the brightness level of a display device when the display device is activated in a dark environment to prevent the temporary vision impairment that can occur when a display device is activated in a dark environment. The algorithm receives the state of the display (e.g. on or in standby mode), and can optionally receive an ambient lighting value from an ambient light sensor and a user-selectable manual brightness adjustment setting to determine whether luminescence shock avoidance should even be triggered, and if it is triggered, how much should the brightness level of the display be limited.

When a display device is in a standby, sleep or powered-down mode to save battery power, the display is at a zero brightness level. When the display is automatically activated, such as when a telephone call is received, the display can turn on to a brightness level determined by the ambient light level detected by the ambient light sensor. If the device is in a car being driven at night, for example, then when a call or other triggering activity is detected, the display brightness level may instantly jump from zero to some predetermined level. Because the user's eyes are likely to be already adjusted to the darkness of the car, the sudden change in display brightness level from can cause luminescence shock and temporary vision impairment, which can be dangerous to the operator of the car, especially if the driver takes a glance at the newly illuminated display.

To avoid luminescence shock, if the display device is off and a call or other triggering activity is detected, the ambient light sensor will turn on and detect a certain ambient light level. In one embodiment, if the detected ambient light level is greater than or equal to a threshold value, then the display device will turn on at a brightness level according to the current display brightness setting. In other words, if the ambient light level is greater than or equal to threshold value, the display will turn on from a zero brightness level to the level defined by the appropriate brightness function as determined by the current display brightness setting. Because the threshold value is chosen such that no luminescence shock is expected for ambient light levels above the threshold value, no adjustment is made to the display brightness level when the display turns on.

However, if the detected ambient light level is below the threshold value, luminescence shock may occur, so the display device will turn on from a zero brightness level to an initially reduced brightness level as compared to what would normally be expected if the brightness function appropriate for the current display brightness level was followed. In other words, the display will initially turn on to a brightness level less than the appropriate brightness function as determined by

the current display brightness setting. This dimmer than usual brightness level is intended to avoid luminescence shock. After some short time period has passed, giving the user's eyes time to adjust, the brightness level can be gradually or instantly increased to the level determined by the appropriate brightness function, which should be closer to ideal for sufficient visibility at the current ambient light level.

In other embodiments, a threshold is not used, and therefore regardless of the detected ambient light level, the display will initially turn on to a brightness level less than the appropriate brightness function as determined by the current display brightness setting. Optionally, as above, after some short time period has passed, the brightness level can be gradually or instantly increased to the level determined by the appropriate brightness function.

If the display device is already on and a call or other triggering activity is detected, there will be no change to the display brightness, regardless of the current light level. In other words, the luminescence shock avoidance algorithm can be employed only when the display device is initially off.

The reduced brightness value may be implemented in a number of different ways. If the detected ambient light level is below a threshold, the reduced display brightness value may be a fixed value, regardless of the current display brightness settings. After some short time period has passed, the brightness level can be gradually or instantly increased to the level determined by the brightness function appropriate for the current display brightness settings. Alternatively, the reduced display brightness value can be a fixed value that is dependent on the current display brightness settings. In another embodiment, the reduced display brightness value is dependent only on the detected ambient light level, regardless of the current display brightness settings. In still other embodiments, the reduced display brightness value is dependent both on the detected ambient light level and the current display brightness settings.

Even in embodiments without an ambient light sensor, and therefore no detected ambient light level, luminescence shock can be avoided. When a telephone call or other triggering activity is detected, the display may initially come on with a reduced brightness value as compared to normal levels. After some short time period has passed, the brightness level can be gradually or instantly increased to normal levels.

In other embodiments, the wavelength of light from the display can be shifted to further reduce luminescence shock. If ambient light levels below a certain threshold are detected when a telephone call or other activity is detected and the display is turned on, the color of the display can be temporarily gamma-shifted into the red region, either alone or in combination with reduced display brightness levels as described above. By gamma-shifting the display towards red light, the brightness of the display will tend to cause the user's pupils to constrict less, so that when the user looks up again at a dark road, for example, the user's vision impairment is reduced. If gamma-shifting is applied in combination with reduced display brightness levels, the display brightness levels may not need to be reduced as much.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary computing system including a display device operable in accordance with a luminescence shock avoidance algorithm according to one embodiment of this invention.

FIG. **2***a* illustrates exemplary brightness functions of ambient light (in lux (one lumen per square meter)) vs. display device brightness or luminance (in nits (one candela per

square meter)) for an exemplary display device according to one embodiment of this invention.

FIG. **2***b* illustrates a luminescence shock avoidance algorithm wherein if the detected ambient light level is below a threshold, the reduced display brightness value may be a fixed value regardless of the current display brightness settings according to one embodiment of this invention.

FIG. **2***c* illustrates a luminescence shock avoidance algorithm wherein if the detected ambient light level is below a threshold, the reduced display brightness value is a fixed value that is dependent on the current display brightness settings according to one embodiment of this invention.

FIG. **2***d* illustrates a luminescence shock avoidance algorithm wherein if the detected ambient light level is below a threshold, the reduced display brightness value is dependent only on the detected ambient light level, regardless of the current display brightness settings according to one embodiment of this invention.

FIG. **2***e* illustrates a luminescence shock avoidance algorithm wherein if the detected ambient light level is below a threshold, the reduced display brightness value is dependent both on the detected ambient light level and the current display brightness settings according to one embodiment of this invention.

FIG. **2***f* illustrates a luminescence shock avoidance algorithm in which no ambient light level is detected and the display device initially turns on at a reduced brightness level before ramping up to normal levels according to one embodiment of this invention.

FIG. **3** is a plot of wavelength vs. pupil sensitivity, showing that the pupils are more sensitive to blue/green light as compared to red light to illustrate the purpose of gamma-shifting according to one embodiment of this invention.

FIG. **4** is a more detailed view of the host processor, ambient light sensor and display device shown in FIG. **1** according to one embodiment of this invention.

FIG. **5***a* illustrates an exemplary mobile telephone that can include luminescence shock avoidance algorithms according to one embodiments of this invention.

FIG. **5***b* illustrates an exemplary digital audio player that can include luminescence shock avoidance algorithms according to one embodiments of this invention.

DETAILED DESCRIPTION

In the following description of preferred embodiments, reference is made to the accompanying drawings which form a part hereof, and in which it is shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the preferred embodiments of the present invention.

A luminescence shock avoidance algorithm can be employed to selectively limit the brightness level of a display device when the display device is activated in a dark environment to prevent the temporary vision impairment that can occur when a display device is activated in a dark environment. The algorithm receives the state of the display (e.g. on or in standby mode), and can optionally receive an ambient lighting value from an ambient light sensor and a user-selectable manual brightness adjustment setting to determine whether luminescence shock avoidance should even be triggered, and if it is triggered, how much should the brightness level of the display be limited.

Although some embodiments of this invention may be described herein in terms of mobile telephones, it should be

understood that other embodiments of this invention may not be so limited, but can be generally applicable to any display device that is capable of automatically waking up from a sleep mode and illuminating the display to a certain level.

FIG. 1 illustrates exemplary computing system **100** operable with touch screen **142** formed from sensor panel **124** and display device **140** that may be used in conjunction with embodiments of this invention. However, it should be understood that the system of FIG. 1 is merely illustrative of a number of different touch screen systems that can be used with embodiments of this invention.

Sensor panel **124** can include a capacitive touch sensor panel capable of detecting touch or hovering within the near-field detection capabilities of the capacitive touch sensors, or a proximity sensor panel capable of detecting hovering outside the near field detection capabilities of the capacitive touch sensors, or a combination of both. Examples of a capacitive touch sensor panel and a proximity sensor panel are described in Applicant's co-pending U.S. application Ser. No. 11/649,998 entitled "Proximity and Multi-Touch Sensor Detection and Demodulation," filed on Jan. 3, 2007, the contents of which are incorporated by reference herein.

Sensor panel **124** can be connected to other components in computing system **100** through connectors integrally formed on the sensor panel, or using flex circuits. Computing system **100** can include one or more panel processors **102** and peripherals **104**, and panel subsystem **106**. The one or more processors **102** can include, for example, ARM968 processors or other processors with similar functionality and capabilities. However, in other embodiments, the panel processor functionality can be implemented instead by dedicated logic such as a state machine. Peripherals **104** can include, but are not limited to, random access memory (RAM) or other types of memory or storage, watchdog timers and the like.

Panel subsystem **106** can include, but is not limited to, one or more analog channels **108**, channel scan logic **110** and driver logic **114**. Channel scan logic **110** can access RAM **112**, autonomously read data from the analog channels and provide control for the analog channels. This control can include multiplexing columns of sensor panel **124** to analog channels **108**. In addition, channel scan logic **110** can control the driver logic and stimulation signals being selectively applied to rows of sensor panel **124**. In some embodiments, panel subsystem **106**, panel processor **102** and peripherals **104** can be integrated into a single application specific integrated circuit (ASIC).

Driver logic **114** can provide multiple panel subsystem outputs **116** and can present a proprietary interface that drives high voltage driver **118**. High voltage driver **118** can provide level shifting from a low voltage level (e.g. complementary metal oxide semiconductor (CMOS) levels) to a higher voltage level, providing a better signal-to-noise (S/N) ratio for noise reduction purposes. The high voltage driver outputs can be sent to decoder **120**, which can selectively connect one or more high voltage driver outputs to one or more panel row inputs **122** through a proprietary interface and enable the use of fewer high voltage driver circuits in the high voltage driver **118**. Each panel row input **122** can drive one or more rows in sensor panel **124**. In some embodiments, high voltage driver **118** and decoder **120** can be integrated into a single ASIC. However, in other embodiments high voltage driver **118** and decoder **120** can be integrated into driver logic **114**, and, in still other embodiments, high voltage driver **118** and decoder **120** can be eliminated entirely.

Computing system **100** can also include host processor **128** for receiving outputs from panel processor **102** and performing actions based on the outputs that can include, but are not

limited to, moving an object such as a cursor or pointer, scrolling or panning, adjusting control settings, opening a file or document, viewing a menu, making a selection, executing instructions, operating a peripheral device connected to the host device, answering a telephone call, placing a telephone call, terminating a telephone call, changing the volume or audio settings, storing information related to telephone communications such as addresses, frequently dialed numbers, received calls, missed calls, logging onto a computer or a computer network, permitting authorized individuals access to restricted areas of the computer or computer network, loading a user profile associated with a user's preferred arrangement of the computer desktop, permitting access to web content, launching a particular program, encrypting or decoding a message, and/or the like.

Host processor **128** can also perform additional functions that may not be related to panel processing, and can be coupled to program storage **132** and display device **130** such as a liquid crystal display (LCD) for providing a user interface (UI) to a user of the device. For example, a luminescence shock avoidance algorithm according to embodiments of this invention can be implemented in software or firmware and executed by host processor **128** to selectively limit the brightness level of a display device when the display device is activated in a dark environment to prevent the temporary vision impairment that can occur when display device **130** is activated in a dark environment.

In some embodiments of this invention, an ambient light sensor **144** may provide a signal or change in state corresponding to the amount of ambient light present. Ambient light sensor **144** can be a photodiode (e.g. a fast pin diode) **146** or any other device (e.g. a phototransistor or other sensing device) known in the art whose current changes as a function of received ambient light, and can include both an infrared (IR) sensor and a visible light sensor.

FIG. 2a illustrates exemplary brightness functions of ambient light (in lux (one lumen per square meter)) vs. display device brightness or luminance (in nits (one candela per square meter)) for an exemplary display device according to embodiments of this invention. The brightness functions in FIG. 2a indicate that, for a given ambient light level (the x-axis), the display device will be set to a particular brightness level (the y-axis). FIG. 2a demonstrates that as the ambient light decreases, less light is needed from the display to maintain sufficient visibility, and as the ambient light increases, more light is needed from the display to maintain sufficient visibility. In FIG. 2a, lines **200**, **202**, **204**, **206** and **208** represent a sampling of brightness functions (or various modified brightness functions) of ambient light vs. display device brightness that can be selected by a user using a manual display brightness control setting, although it should be noted that the brightness functions need not be largely linear, but can be non-linear and can even include discrete steps. The brightness functions may be mathematical expressions computed by a processor, or look-up tables stored in memory. In the example of FIG. 2a, line **200** can be the default (neutral) display brightness function, but if the user desires a lower display brightness, the control setting can be adjusted down, either in continuous or discrete steps, until an absolute minimum display brightness function **202** is reached. Note that in the example of FIG. 2a, when function **202** hits a minimum ambient light level **214**, it does not drop below a minimum display brightness level **210**, and thus the display will always be illuminated to some degree, even in absolute darkness. However, it should be understood that minimum levels **210** and **214** are not required.

Conversely, if the user desires a higher display brightness, the control setting can be adjusted up, either in continuous or discrete steps, passing through brightness functions **204** and **206**, until an absolute maximum display brightness function **208** is reached. Note that in the example of FIG. **2**a, function **208** is maintained at maximum display brightness level **212**. At this setting, there is essentially no longer any sensitivity to ambient light, as the display brightness setting is constant, regardless of the ambient light level. It also be understood that in other embodiments, there may be no manual display brightness control, and only a single brightness function (e.g. default function **200**) may be employed.

FIG. **2**a also illustrates that when the display device is in a standby, sleep or powered-down mode to save battery power, the display is at a zero brightness level **216**. When the display is automatically activated, such as when a telephone call is received, the display will turn on to the brightness level determined by the ambient light level detected by the ambient light sensor. For example, if the device was in a brightly lit room when a call is received, the display brightness level may jump from point **218** to point **220**. Because the user's eyes are likely to be already adjusted to the lighting in the room, the sudden change in display brightness level from point **218** to point **220** should not cause any luminescence shock. However, if the device is in a car being driven at night, for example, when a call is received, the display brightness level may jump from point **222** to point **224**. Although the display brightness level of point **224** is far less than point **220**, nevertheless because the user's eyes are likely to be already adjusted to the darkness of the car, the sudden change in display brightness level from point **222** to point **224** can cause luminescence shock and temporary vision impairment, which can be dangerous to the operator of the car.

To avoid luminescence shock, an algorithm may be applied as follows. If the display device is off and a call or other triggering activity is detected, the ambient light sensor will turn on and detect a certain ambient light level. In one embodiment, if the detected ambient light level is greater than or equal to a luminescence shock threshold value **226**, then the display device will turn on at a brightness level according to the current display brightness setting. In other words, if the ambient light level is greater than or equal to threshold value **226**, the display will turn on from a zero brightness level to the level defined by the appropriate brightness function as determined by the current display brightness setting (e.g. from point **218** to point **220**). Threshold value **226** can be determined empirically and then used as a fixed value in the algorithm, or it can be user programmable. Because threshold value **226** is chosen such that no luminescence shock is expected for ambient light levels above the threshold value, no adjustment is made to the display brightness level when the display turns on.

However, if the detected ambient light level is below threshold value **226**, luminescence shock may occur, so the display device will turn on from a zero brightness level to an initially reduced brightness level as compared to what would normally be expected if the brightness function appropriate for the current display brightness level was followed. In other words, the display will initially turn on to a brightness level less than the appropriate brightness function as determined by the current display brightness setting (e.g. from point **222** to point **228**, which is less than point **224**). This dimmer than usual brightness level is intended to avoid luminescence shock. After some short time period has passed (e.g. five seconds), giving the user's eyes time to adjust, the brightness level can be gradually or instantly increased to the level determined by the appropriate brightness function (see arrow

230), which should be closer to ideal for sufficient visibility at the current ambient light level.

In other embodiments, threshold **226** is not used, and therefore regardless of the detected ambient light level, the display will initially turn on to a brightness level less than the appropriate brightness function as determined by the current display brightness setting. Optionally, as above, after some short time period has passed, the brightness level can be gradually or instantly increased to the level determined by the appropriate brightness function.

If the display device is already on and a call or other triggering activity is detected, there will be no change to the display brightness, regardless of the current light level. In other words, the luminescence shock avoidance algorithm can be employed only when the display device is initially off.

The reduced brightness value may be implemented in a number of different ways. FIG. **2**b illustrates one embodiment of this invention wherein if the detected ambient light level is below threshold **226**, the reduced display brightness value may be a fixed value **240**, regardless of the current display brightness settings. After some short time period has passed, the brightness level can be gradually or instantly increased to the level determined by the brightness function appropriate for the current display brightness settings. In the example of FIG. **2**b, two brightness functions **200** and **204** are shown representing two different possible current display brightness settings. If the current display brightness settings correspond to brightness function **200**, then the display device turns on to a reduced brightness level **240** (see arrows **232**), and then after some time has passed, the display device returns to the brightness levels determined by brightness function **200** (see arrows **234**). Even if the current display brightness settings correspond to brightness function **204**, the display device turns on to the same reduced brightness level **240** (see arrows **236**), and then after some time has passed, the display device returns to the brightness levels determined by brightness function **204** (see arrows **238**).

FIG. **2**c illustrates one embodiment of this invention wherein if the detected ambient light level is below threshold **226**, the reduced display brightness value is a fixed value that is dependent on the current display brightness settings. After some short time period has passed, the brightness level can be gradually or instantly increased to the level determined by the brightness function appropriate for the current display brightness settings. In the example of FIG. **2**c, two brightness functions **200** and **204** are shown representing two different possible current display brightness settings. If the current display brightness settings correspond to brightness function **200**, then the display device turns on to a reduced brightness level **240** associated with brightness function **200** (see arrows **232**), and then after some time has passed, the display device returns to the brightness levels determined by brightness function **200** (see arrows **234**). If the current display brightness settings correspond to brightness function **204**, the display device turns on to a higher reduced brightness level **246** associated with brightness function **204** (see arrows **242**), and then after some time has passed, the display device returns to the brightness levels determined by brightness function **204** (see arrows **244**).

As the example embodiment of FIG. **2**c illustrates, the fixed values **240** and **246** can depend on the current display brightness settings. For example, the higher the current display brightness settings, the higher the fixed value. At the lowest possible current display brightness settings, the fixed value can be the minimum display brightness value **210** (see FIG. **2**a).

FIG. 2*d* illustrates one embodiment of this invention wherein if the detected ambient light level is below threshold **226**, the reduced display brightness value is dependent only on the detected ambient light level, regardless of the current display brightness settings. After some short time period has passed, the brightness level can be gradually or instantly increased to the level determined by the brightness function appropriate for the current display brightness settings. In the example of FIG. 2*d*, two brightness functions **200** and **204** are shown representing two different possible current display brightness settings. If the current display brightness settings correspond to brightness function **200**, then the display device turns on to a reduced brightness level as determined by the detected ambient light level and reduced brightness function **248** (see arrows **250**). Note that although reduced brightness function **248** is shown in FIG. 2*d* as a piecewise linear function, any type of function could be used, as long as it represents a reduced brightness level. The reduced brightness function may be a mathematical expression computed by a processor, or may be a look-up table stored in memory. After some time has passed, the display device returns to the brightness levels determined by brightness function **200** (see arrows **252**). Even if the current display brightness settings correspond to brightness function **204**, the display device turns on to the same reduced brightness level as determined by the detected ambient light level and reduced brightness function **248** (see arrows **254**), and then after some time has passed, the display device returns to the brightness levels determined by brightness function **204** (see arrows **256**).

FIG. 2*e* illustrates one embodiment of this invention wherein if the detected ambient light level is below threshold **226**, the reduced display brightness value is dependent both on the detected ambient light level and the current display brightness settings. After some short time period has passed, the brightness level can be gradually or instantly increased to the level determined by the brightness function appropriate for the current display brightness settings. In the example of FIG. 2*e*, two brightness functions **200** and **204** are shown representing two different possible current display brightness settings. If the current display brightness settings correspond to brightness function **200**, then the display device turns on to a reduced brightness level as determined by the detected ambient light level and reduced brightness function **248** associated with brightness function **200** (see arrows **250**). After some time has passed, the display device returns to the brightness levels determined by brightness function **200** (see arrows **252**). If the current display brightness settings correspond to brightness function **204**, the display device turns on to a reduced brightness level as determined by the detected ambient light level and reduced brightness function **254** associated with brightness function **204** (see arrows **256**), and then after some time has passed, the display device returns to the brightness levels determined by brightness function **204** (see arrows **258**).

Even in embodiments without an ambient light sensor, and therefore no detected ambient light level, luminescence shock can be avoided. FIG. 2*f* illustrates one embodiment of this invention in which when the display device is on, it remains at a constant level **260**, regardless of the ambient light level. In some embodiments, this constant level **260** can be adjusted up or down as indicated by arrows **262** using a manual display brightness control. When a telephone call or other triggering activity is detected, the display may initially come on with a reduced brightness value **264** as compared to line **260** (see arrows **266**). After some short time period has passed, the brightness level can be gradually or instantly increased to the level determined by brightness level **260** (see arrows **268**).

In some embodiments of this invention, the wavelength of light from the display can be shifted to further reduce luminescence shock. FIG. **3** is a plot of wavelength vs. pupil sensitivity, showing that the pupils are more sensitive to blue/green light (i.e. the pupils tend to constrict more) as compared to red light. Thus, if ambient light levels below a certain threshold are detected when a telephone call or other activity is detected and the display is turned on, the color of the display can be temporarily gamma-shifted into the red region, either alone or in combination with reduced display brightness levels as described above. By gamma-shifting the display towards red light (see arrow **300**), the brightness of the display will tend to cause the user's pupils to constrict less, so that when the user looks up again at a dark road, for example, the user's vision impairment is reduced. If gamma-shifting is applied in combination with reduced display brightness levels, the display brightness levels may not need to be reduced as much.

FIG. **4** is a more detailed view of the host processor, ambient light sensor and display device shown in FIG. **1**. In FIG. **4**, host processor **400** receives information on detected ambient light levels from ambient light sensor **402** through an interface which can include and I.sup.2C digital serial interface **404**. Host processor **400** can execute luminescence shock software or firmware **406** and control the brightness of display device **408** using control signals **410**. In addition, gamma-shift logic **412**, which can be a color lookup table, can perform the gamma-shifting described above to alter the RGB inputs to display device **408** and shift the display to the red spectrum as described above.

FIG. **5***a* illustrates an exemplary mobile telephone **536** having sensor panel **524** and display device **530** and a processor that can include the luminescence shock avoidance algorithms as described above according to embodiments of this invention. FIG. **5***b* illustrates an exemplary digital audio/video player **538** having sensor panel **524** and display device **530** and a processor that can include luminescence shock avoidance algorithms as described above according to embodiments of this invention. The mobile telephone and digital audio/video player of FIGS. **5***a* and **5***b* can advantageously benefit from the luminescence shock avoidance algorithms because they can limit the amount of temporary vision impairment that can occur when a previously dark display device is illuminated in a dark environment, which can be hazardous in certain situations such as when the user is driving a car at night.

Although the present invention has been fully described in connection with embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A method, comprising:
   activating a display in an electronic device, wherein activating the display comprises:
      with a sensor in the electronic device, detecting a current ambient light level at the display; and
      after detecting the current ambient light level, increasing a brightness of the display to an initial brightness level that is at least partly based on the current ambient light level, wherein increasing the brightness of the display to the initial brightness level comprises, when the current ambient light level is below a threshold, limiting an initial brightness level of the display to the initial brightness level.

2. The method defined in claim **1** further comprising:

when the current ambient light level is below the threshold and after an initial period of time, increasing the brightness level of the display from the initial brightness level to a given brightness level based on the current ambient light level.

3. The method defined in claim **1** further comprising detecting a triggering activity, wherein activating the display comprises activating the display in response to detection of the triggering activity.

4. An electronic device, comprising:

a display;

an ambient light sensor; and

circuitry coupled to the display and to the ambient light sensor, wherein the circuitry, prior to activating the display, uses the ambient light sensor to detect an ambient light level at the electronic device using the ambient light sensor and subsequently activates the display and adjusts the brightness of the display to an initial brightness level that is at least partially dependent upon the detected ambient light level, wherein activating the display comprises increasing the brightness of the display to the initial brightness level and limiting the initial brightness level to the initial brightness level when the ambient light level is below a threshold.

5. The electronic device defined in claim **4** wherein the electronic device comprises a mobile telephone and wherein the circuitry activates the display in response to a triggering event.

6. The electronic device defined in claim **4** further comprising:

a user input device, wherein the electronic device comprises a mobile telephone and wherein the circuitry activates the display in response to user input received through the user input device.

7. The electronic device defined in claim **4** wherein the display comprises a touch screen display.

8. The electronic device defined in claim **4** wherein the circuitry adjusts the brightness of the display from a zero

brightness level to the initial brightness level that is at least partially dependent upon the detected ambient light level.

9. A method for avoiding luminescence shock in an electronic device having a display and an ambient light sensor, the method comprising:

during normal operations of the electronic device, using a brightness function to determine an appropriate brightness level of the display, wherein the brightness function takes into account current ambient light levels as measured by the ambient light sensor;

deactivating the display; and

activating the display, wherein activating the display comprises:

with the ambient light sensor, measuring the current ambient light level;

if the current ambient light level is below a given threshold, limiting an initial brightness of the display to a given brightness level, wherein the given brightness level is lower than the appropriate brightness level as determined by the brightness function for the current ambient light level; and

after a period of time, increasing a brightness of the display to the appropriate brightness level as determined by the brightness function for the current ambient light level.

10. The method defined in claim **9** wherein the sensor and the display device are part of a mobile telephone and wherein activating the display comprises activating the display in response to detecting an incoming call to the mobile telephone.

11. The method defined in claim **9** wherein the sensor and the display device are part of a mobile telephone, wherein the display device comprises a touch screen, and wherein activating the display comprises activating the display in response to detecting an incoming call to the mobile telephone.

* * * * *